Assessment of the Use of Dispersants on Oil Spills in California Marine Waters

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Abstract

This project was a comprehensive assessment of technical issues associated with using dispersants to cleanup oil spills from offshore production sources and transportation sources in California. The study examined both operational issues: 1) dispersibility of produced and imported oils; 2) capabilities of California response resources to deal with typical spills; and 3) limiting effects of California offshore physical environment (e.g., frequency of fog, rain) on dispersant operations; and environmental issues: 1) risks associated with typical spills; and 2) potential net environmental benefit of chemically dispersing these spills.

Most crude oils produced in California offshore areas are heavy (average API gravity of all oils is 20.2^{o}) and border on the undispersible range. On the other hand, most of the 2 to 3 dozen crude oils imported annually are somewhat lighter. Alaska North Slope crude oil, which represents 50% of the annual imports is dispersible when fresh. Modeling of spill behaviour suggest that most of produced oils and some imported oils emulsify quickly. These oils weather quickly to the point where they are no longer dispersible and therefore have very narrow time-windows (TW) for chemical dispersion.

Net environmental benefit (NEB) of dispersants was considered by analyzing the impact of spill scenarios. Two important features of this analysis were that: 1) existing government-sponsored natural resource databases (environmental sensitivity mapping) were used to describe resource distributions and vulnerability; and 2) the Ecological Risk Assessment (ERA) method that is currently in use in California was used to describe impacts. The main conclusion from the NEB analyses was that dispersant use offered a clear net environmental benefit in all scenarios analyzed.

1. Introduction

This project was a comprehensive assessment of operational and environmental factors associated with dispersant use in California marine waters. Spills from both transportation and production sources were addressed, focusing on: a) amenability of the oils in question to dispersants; b) time windows (TW) for chemical dispersion; c) operational, logistic and feasibility issues; and d) net environmental benefits or drawbacks of dispersant use on California spills. The paper contains a summary of the main findings. Detailed descriptions of methods are reported in the full technical report S.L. Ross (2002).

2. Likely Dispersibility of California Oils

The properties of the oils involved are important from the dispersant perspective because dispersants are effective only if the spilled oil has a relatively low viscosity at the time of treatment. Three types of oils considered here are:

1. crude oils produced in California Outer Continental Shelf waters;
2. oils imported from Alaska and foreign countries into California ports; and
3. fuel oils that could be spilled from a variety of marine industrial activities (e.g., fuel tanks from ships, cargoes of small tankers).

2.1 Oils Produced in California Waters

Oils from the 22 producing fields in the federally controlled Pacific Outer Continental Shelf Region (POCSR) are summarized in Table 1. Until recently, the properties of these oils were not well known, but in 1999, an MMS-sponsored study produced information useful in assessing their dispersibility (Jokuty et al. 1999). Most POCSR oils are heavy, with an average API gravity of all oils of 20.2^{o}. These values border on the undispersible range, based on the criteria of the International Tanker Owners Pollution Federation (1987), as modified by S.L. Ross (unpublished). This may suggest that POCSR oils are not be good candidates for chemical dispersion, but a more thorough analysis, by modeling, will provide better insight into this.

2.2 Imported Crude Oils

The two to three dozen oils imported annually into California in 1999-2001 are listed in Table 2. Alaska North Slope crude oil represents 50% of each annual total. It was not practical to model each of the imported oils, so in order to reduce the number of oils, we have included only the oils that make up 90% of imported volume (in gray in Table 2). Some properties of these oils are summarized in Table 3. Based on API gravity information, most of these oils appear to be dispersible when fresh. However, modeling work is required to assess their TW for dispersants. Information needed to assess TW through modeling is available for only the five oils identified in Table 3.

2.3 Refined Oils

Information about the fuel oils and other refined products transported in California waters was not available and so only diesel fuel was included in this analysis.

Table 1 POCSR Oil Fields, Platforms and Oils

Oil Field Name	Platform Name	POCSR API Gravity [1]	MMS/EC Oil Catalog [2] Name	API Gravity	Average Annual Production 1996-2000 (BBLS) [3]
Beta	Ellen Elly Eureka Edith	17.3 - 18.3	Beta	13.7	2,364,019
Carpinteria	Hogan Houchin Henry	24.2	Carpinteria	22.9	808,641
Dos Cuadras	Hillhouse A B C	24.3	Dos Cuadras	25.6	2,473,702
Hondo	Hondo Harmony	21.5	Hondo	19.6	13,938,138
Hueneme	Gina	20.9	Port Hueneme		222,569
Pescado	Heritage	21.5			11,968,537
Pitas Point	Habitat		Pitas Point	38	3,099
Point Arguello	Hidalgo Harvest Hermosa	22.2	Point Arguello Commingled Point Arguello Heavy Point Arguello Light	21.4 18.2 30.3	9,627,539
Point Pedernales	Irene	21.1	Platform Irene	11.2	3,294,989
Sacate					2,187,755 [4]
Santa Clara	Gilda Grace	20.9	Santa Clara	22.1	1,145,562
Sockeye	Gail	21.6	Sockeye Sockeye Commingled Sockeye Sour Sockeye Sweet	26.2 19.8 18.8 29.4	1,735,719

(1) From a table presented at a POCSR workshop, June 7, 2001. From samples taken between Jan, 99 & Oct, 99
(2) Jokuty,P.,S. Whiticar, Z. Wang, B. Fieldhouse, and M. Fingas,
A Catalogue of Crude Oil and Oil Product Properties for the Pacific Region, 264p 1999.
(3) Pacific Production Information and Data Available in ASCII Files for Downloading:
http://www.gomr.mms.gov/homepg/pubinfo/pacificfreeasci/product/pacificfreeprod.html
(4) Sacate shows up in the production files in 1999 with 0.25 MBbl and then in 2000 with 2.0 MBbls

3. Time Windows and Behaviour of Spills

The time-window (TW) available for dispersant use is the length of time required for the spilled oil to weather and emulsify to the point that it is too viscous to be amenable to chemical dispersion. In the present context TW is as important as basic dispersibility of the fresh oil because it represents the time available for responders to disperse all of the oil. The best information regarding the emulsification rate of any oil is obtained from actual spills, but this data is not generally available. An alternate approach is to model the changes in spill-related characteristics of the oil with time during a spill. In this study, two sets of computer simulations were performed: a) one to determine the TW of all oils under standardized conditions; and b) a second to determine TW for selected oils in scenarios of local interest. In all cases, dispersibility was taken to be a function of oil viscosity. The change in oil viscosity with time was computed using the SL Ross Oil Spill Model (SLROSM) that uses the following algorithms: evaporation (Stiver and Mackay 1983), emulsification (Mackay and Zagorski 1982) and change in oil viscosity (Mooney 1951), as described in Belore and Buist (1994) and S.L. Ross 2001 and 2002. Example oil properties used in these calculations are included in the appendix below.

Table 2 Summary of California Crude Oil Imports for 1999, 2000 and 2001

SUMMARY: OILS RANKED BY VOLUME (1999)			
Name of Oil	Volume (1000 bbls)	Fraction of Total	Cumulative Total
Alaska North Slope	188743	56.3%	56.3%
Oriente	28274	8.4%	64.7%
FAO Blend	26546	7.9%	72.6%
Basrah Light	21410	6.4%	79.0%
Arab Extra Light	9617	2.9%	81.9%
Arab Light	5657	1.7%	83.6%
Maya	9987	3.0%	86.6%
Escalante	8063	2.4%	89.0%
Arab Medium	5751	1.7%	90.7%
Minas	4774	1.4%	92.1%
Loreto	4637	1.4%	93.5%
Kuwait	3074	0.9%	94.4%
Oriente Lt.	3069	0.9%	95.3%
Sumatran Heavy	2664	0.8%	96.1%
Eocene	2482	0.7%	96.8%
Bintulu	1469	0.4%	97.3%
Dai Hung	1199	0.4%	97.6%
Isthmus	1196	0.4%	98.0%
Tapis Blend	1087	0.3%	98.3%
Lucula	869	0.3%	98.6%
Magellanes	749	0.2%	98.8%
Djeno Blend	723	0.2%	99.0%
Burgan	627	0.2%	99.2%
Seria Lt	584	0.2%	99.4%
Basrah Heavy	455	0.1%	99.5%
Lagomedio	384	0.1%	99.6%
Cano Limon	381	0.1%	99.7%
???? (Mexico)	347	0.1%	99.8%
BCF 24	262	0.1%	99.9%
???? (Malaysia)	244	0.1%	100.0%

SUMMARY: OILS RANKED BY VOLUME (2000)			
Name of Oil	Volume (1000 bbls)	Fraction of Total	Cumulative Total
Alaska North Slope	163233	47.7%	47.7%
FAO Blend	39955	11.7%	59.4%
Oriente	34941	10.2%	69.6%
Arab Medium	17083	5.0%	74.6%
Arab Light	9396	2.7%	77.4%
Maya	12863	3.8%	81.1%
Yemen	9802	2.9%	84.0%
Basrah Light	9507	2.8%	86.8%
Escalante	6993	2.0%	88.8%
Minas	4110	1.2%	90.0%
Arab Extra Light	4065	1.2%	91.2%
Eocene	2825	0.8%	92.0%
Barrow Island	2801	0.8%	92.9%
Tapis Blend	2526	0.7%	93.6%
Dai Hung	2367	0.7%	94.3%
Cossack	2345	0.7%	95.0%
BCF 24	2320	0.7%	95.7%
Kuwait	2161	0.6%	96.3%
???? (Mexico)	1995	0.6%	96.9%
Oriente Light	1921	0.6%	97.4%
Basrah Heavy	1787	0.5%	98.0%
Loreto	1494	0.4%	98.4%
Cano Limon	1237	0.4%	98.8%
Taching (Daqing)	835	0.2%	99.0%
Burgan	780	0.2%	99.2%
Bachaquero	694	0.2%	99.4%
Murban	423	0.1%	99.6%
Seria Light	414	0.1%	99.7%
Griffin	411	0.1%	99.8%
Bintulu	384	0.1%	99.9%
Champion Export	237	0.1%	100.0%
Dubai	54	0.0%	100.0%

SUMMARY: OILS RANKED BY VOLUME (2001*)			
Name of Oil	Volume (1000 bbls)	Fraction of Total	Cumulative Total
Alaska North Slope**	48091	49.7%	49.7%
Arab Medium	9092	9.4%	59.1%
FAO Blend	6531	6.7%	65.8%
Maya	6130	6.3%	72.1%
Arab Light	5325	5.5%	77.6%
Yemen	4149	4.3%	81.9%
Oriente	3527	3.6%	85.6%
Cossack	2566	2.7%	88.2%
Murban	2282	2.4%	90.6%
Escalante	2176	2.2%	92.8%
Arab Extra Light	1690	1.7%	94.6%
Seria Light	811	0.8%	95.4%
BCF 24	804	0.8%	96.2%
Vasconia	745	0.8%	97.0%
Minas	623	0.6%	97.6%
Lucula	560	0.6%	98.2%
???? (Australia)	433	0.4%	98.7%
???? (Congo)	399	0.4%	99.1%
Arab Heavy	332	0.3%	99.4%
Loreto	290	0.3%	99.7%
Jackson Blend	196	0.2%	99.9%
Cano Limon	75	0.1%	100.0%

*data for January to April 2001

**note: volume for Alaska estimated assuming 12% decline from 2000, which reflects trend of last five years

In above three charts, a total of ten oils (highlighted) represent 90% of the volume in a given period.

3.1 Time Windows for Oils Under Standard Conditions

The modeling analysis considered batch spills of 1000-bbl and 10,000-bbl occurring under average environmental conditions for California waters. Of all oils produced in California (Table 1) or imported (Table 2), only 17 have been characterized well enough to permit modeling of time-dependent properties during spills. These 17, plus No. 2 fuel oil, have been analyzed in this study.

Based on the computer simulations, these 18 oils can be divided into three categories of "emulsion formation tendency" (Table 4). Clearly, 12 oils are highly emulsifiable (called Hi-E oils) and have a very narrow TW. These oils, that include Arab Medium crude and Pt. Arguello crude, start to emulsify after only 10% or less of the spill has evaporated. For these two oils, 1000-barrel spills will reach a viscosity of 2000 cP within 4 hours of the spill, 5000 cP in 6 to 7 and 20,000 cP in 22 to 23 hours. Assuming a viscosity cut-off point for effective dispersion in the range of 5000 to 20,000 cP, the TW for dispersant response is only 4 to 23 hours.

The next category of oils, called Av-E oils, will start to emulsify after 11 to 29% evaporation. ANS crude is representative of this class and has TW of 38 to 67 hours.

The final category, called Low-E oils, do not emulsify regardless of the extent of evaporation, allowing an unlimited TW for dispersants. In this study there were only two examples of this category, namely diesel oil and Pitas Point crude (a heavy gas condensate).

In summary, the opportunity for using dispersants effectively on the example oils in this study is limited. For the produced oils the situation is not promising, as only a few oils appear to be amenable to dispersion, though some success might be possible if spill circumstances are right and the response is rapid. The situation is different for the imported oils, since Alaska North Slope crude, which represents about 50% of the oil spill risk from tankers in the state, appears to be quite amenable to dispersion. Also, diesel oil, which appears to be spilled relatively frequently, is also a good candidate for dispersion.

4. Spill Scenario Modeling

In general, TW varies with a number of factors other than oil type, including spill type (e.g., blowout vs. batch spill), spill volume, and environmental conditions. To assess the potential influence of these factors on California spills, 15 additional simulations were conducted analyzing typical production and transportation spills occurring under average environmental conditions (Table 5). Vessel spill scenarios were selected from existing Area Contingency Plans (ACP) (USCG and California OSPR 2000) and blowout scenarios were based on operators' contingency plans filed with MMS (e.g., Arguello Incorporated. 2001, Venoco Inc. 2001). Twelve of the scenarios involve production facilities and the remaining three are generic spills selected to span the range of vessel spill sizes identified in existing ACPs.

The common thread in the behavior of the production spills is the rapid emulsification and high persistence of the oils. The TW for dispersants in batch spills (Scenarios 3, 6, 9 and 12) range from 2 to 20 hours. Because of this small TW, it may be difficult to mount dispersant operations for these spills.

Table 3 Some Properties of Top Ten Oils Shipped to California, 1999-2001

Oil Type	Identifying Properties				Sufficient test data
	API gravity	Sulfur content, %	Viscosity at 15°C, cP	Pour point, °C	
Alaska North Slope	26.8	1.15	17	-15	Yes
Arab Medium	30.8	2.4	29	-10	Yes
Maya	21.8	3.3	299	-20	Yes
Arabian Light	33.4	1.77	14	-53	Yes
Oriente	29.2	1.01	85	-4	Yes
Basrah Light	33.7	1.95	≈20	-15	No
Escalante/Canadon Seco	24.1	0.19	?	?	No
Arabian Extra Light	37.9	1.2	?	?	No
FAO Blend	31.0	3.0	?	?	No
Yemen	31.0	0.6	?	?	No

1. Sufficient spill-test data for modeling purposes?

For continuous spills, the above sea and sub-sea blowouts differ mainly in their thickness, with slicks from subsea blowouts being far thinner initially than surface blowouts. When lighter oils are involved (e.g., Pt. Arguello Light and Sockeye crude oils), slicks are very thin initially (5 to 14 microns); they appear to disperse immediately by natural means and do not require dispersants. With heavier oils, slicks are thicker and emulsify to an undispersible state immediately, generally in two hours or less. Even though these spills are continuous releases, the oil emulsifies so rapidly that it is questionable whether dispersants would be effective even if applied as soon as the oil surfaces. The picture is somewhat more optimistic for above sea blowouts because, in scenarios involving Av-E oils (e.g., Sockeye Sweet), TW can be longer, up to eight hours, allowing plenty of time for dispersion. However, above sea blowouts of Hi-E oils emulsify almost immediately as they do in subsea blowouts leaving little time for chemical dispersion.

For batch spills from ships, spills of three sizes involving three different oil types were considered. Spills of 250,000, 10,000 and 3000 barrels were considered for Alaska North Slope and Arab Medium crude oils. Diesel spills of 10,000 barrels and 3000 barrels were also considered. The two crude oils differ markedly in their behavior. The ANS crude scenarios have longer TW (104 to 166 hours) than the Arab Medium crude scenarios (8 to 22 hour) because of the longer delay in onset of emulsification. The TW shrinks as the spill volume decreases for all batch spills. The TWs for ANS scenarios drop from 166 to 90 to 74 hours for the 250,000, 10,000 and 3,000 barrel spills, respectively under 5-knot wind conditions. The same trend holds for different oil types and wind speeds. Diesel fuel spills do not form emulsions and are therefore dispersible up to the time that they dissipate naturally.

Table 4 POCSR and Imported California Oils That Have Undergone Spill-Related Testing

Crude oil name	API Gravity	Fresh oil Pour Point °C	Oil Viscosity @ 15°C at various weathered states			Emulsion formation tendency	Size of "Window of Opportunity" for successful dispersant use	Hours for oil to reach specified viscosity in 5 m/s (10 kt) winds and at 15°C water temperature					
								1000 Barrel Batch Spill			10,000 Barrel Batch Spill		
			0%	~ 15%	~ 25%			2000 cP	5000 cP	20,000 cP	2000 cP	5000 cP	20,000 cP
HIGHLY EMULSIFIABLE OILS (Hi-E Oils) (Emulsion forms at 0 to10 % oil evaporation)													
Arab Medium	29.5	-10	29	91	275	Yes @ 0%	very narrow	4.2	6.4	22.0	4.9	7.7	39.0
Arab Light[a]	31.8	-53	14	33	94	Yes @ 0%	narrow[a]	10.0	36.0	Disp @41 hr	13.3	68.8	Disp @ 68
Hondo	19.6	-15	735	9583	449700	Yes @ 0%	very narrow	2.0	3.0	5.5	2.4	3.7	6.2
Hueneme	14.8	-9	4131	20990		Yes @ 0%	very narrow	0.0	0.5	1.9	0.0	0.5	1.9
Maya	21.8	-20	299	99390		Yes @ 0%	very narrow	1.6	2.3	4.8	1.8	2.6	5.1
Oriente	25.9	-4	85		6124	Yes @ 0%	very narrow	2.2	3.2	5.2	2.8	3.8	6.4
Pt Arguello Co-	21.4	-12	533	41860	2266000	Yes @ 0%	very narrow	1.6	2.6	4.3	1.7	2.9	4.9
Pt Arguello Heavy	18.2	-4	3250		4953000	Yes @ 0%	very narrow	0.0	0.5	1.7	0.0	0.5	1.9
Pt Arguello Light	30.3	-22	22	183	671	Yes @ 0%	very narrow	4.4	6.9	23.0	5.1	8.1	42.0
Santa Clara	22.1	-3	304	1859	22760	Yes @ 0%	very narrow	2.6	3.8	6.6	2.9	4.4	7.9
Sockeye	26.2	-12	45	163	628	Yes @ 0%	very narrow	3.9	5.6	13.2	4.3	6.4	20.4
Sockeye Sour	18.8	-22	821	8708	475200	Yes @ 0%	very narrow	1.1	1.9	3.1	1.3	2.0	3.5
MEDIUM EMULSIFIABLE OILS (Av-E Oils) (Emulsion forms at 11 to 29 % oil evaporation)													
Alaska North Slope	26.8	-15	17	110	650	Yes @ 26%	narrow	37.9	39.7	43.3	60.7	62.2	66.7
Carpinteria	22.9	-21	164	3426		Yes @ 11%	narrow	5.6	6.6	8.9	8.3	9.5	12.0
Dos Cuadras	25.6	-30	51	187	741	Yes @ 11%	narrow	5.4	7.0	11.0	7.4	8.9	14.3
Sockeye Sweet	29.4	-20	20	39	321	Yes @ 17%	narrow	8.6	10.6	28.8	11.6	14.1	47.8
OILS THAT DO NOT EMULSIFY (No-E Oils) (Emulsion does not form)													
Diesel	39.5	-30	8	25	100	No	Very wide	60.0	Disp @ 69 hr		101.0	Disp @ 111 hr	
Pitas Point	38.0	<-60	2		2	No	Very wide	Disp @ 2.3 hr			Disp @ 3.5 hr		

a. Although Arab Light is a highly emulsifiable crude oil, the viscosity of its emulsion is estimated to be relatively low, explaining the "narrow" time window designation rather than "very narrow".

Table 5 California Marine Oil Spill Scenarios

#	Spill Description	Spill Volume	Oil	Comments
Local Production Spill Scenarios				
1	Hermosa Platform -subsea blowout	1070 bopd for 30 days	Pt. Arguello Heavy	water depth of 184 m 480 scf gas / bbl oil, 14 knot winds, 14 °C
2	Hermosa -surface blowout	1070 bopd for 30 days	Pt. Arguello Heavy	480 scf gas / bbl oil, 14 knot winds, 14 °C
3	Hermosa Platform - batch	2217 bbl	Pt. Arguello Commingle d	pipeline discharge, 14 knot winds, 14 °C
4	Hidalgo Platform -subsea blowout	973 bopd for 30 days	Pt. Arguello 4 a) Heavy 4 b) Light	water depth of 130 m, 14 knot winds, 14 °C, 763 scf gas / bbl oil
5	Hidalgo -surface blowout	973 bopd for 30 days	Pt. Arguello 5 a) Heavy 5 b) Light	763 scf gas / bbl oil, 14 knot winds, 14 °C
6	Hidalgo Platform - batch	500 bbl	Pt. Arguello 6 a) Heavy 6 b) Light	Pipeline discharge, 14 knot winds, 14 °C
7	Harvest Platform -subsea blowout	5000 bopd for 30 days	Pt. Arguello Heavy	water depth of 206 m, 14 knot winds, 14 °C, 1435 scf gas / bbl oil
8	Harvest Platform -surface blowout	5000 bopd for 30 days	Pt. Arguello Heavy	1435 scf gas / bbl oil, 14 knot winds, 14 °C
9	Harvest Platform -batch	292 bbl	Pt. Arguello Heavy	Pipeline discharge, 14 knot winds, 14 °C
10	Gail Platform -subsea blowout	882 bopd for 30 days	Sockeye crude	water depth of 225 m, 7 knot winds, 17 °C, 4071 scf gas / bbl oil
11	Gail Platform -surface blowout	882 bopd for 30 days	Sockeye crude	4071 scf gas / bbl oil, 7 knot winds, 17 °C
12	Gail Platform -batch	a) 2068 bbl b) 131 bbl	Sockeye crude	Platform vessels and piping, 7 knot winds, 17 °C
Vessel Spills				
13	Very Large Batch	250,000 bbl	13 a) ANS 13 b) Arab Med	Los Angeles area in Summer 5 knot winds 18 °C
15	Large Batch	10,000 bbl	15 a) ANS 15 b) Arab Med 15 c) Diesel	Los Angeles area in Summer 5 knot winds 18 °C
17	Small Batch	3000 bbl	17 a) ANS 17 b) Arab Med 17 c) Diesel	Los Angeles area in Summer 5 knot winds 18 °C

Table 6a. Spill Scenario Modeling Result Summary: Spills from Local Production Facilities

	Spill Scenario Identifier (refer to Table 5 for full description of scenario)															
	1	2	3	4a	4b	5a	5b	6a	6b	7	8	9	10	11	12a	12b
Spill Information																
Emulsification Tendency	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Hi
Volume Spilled (bbl)	32100	32100	2217	29190	29190	29190	29190	500	500	150000	150000	292	26460	26460	2068	131
Discharge Rate (BOPD)	1070	1070	batch	973	973	973	973	batch	batch	5000	5000	batch	882	882	batch	batch
Viscosity (cP)																
Time to Visc.>5000 cP (hr)	0.0	0.0	1.8	0.0	-	0.0	2.0	0.17	4.7	0	0	0.17	-	4.6	7.0	5.6
Time to Visc.>20000 cP(hr)	0.01	0.0	3.1	0.01	-	0.0	3.5	1.0	22	0.01	0	1.0	-	8.9	12.4	9.6
Time to Loss of Slick (hr)	>720	>720	>720	216	0.16	>720	>720	>720	141	>720	>720	>720	0	>720	>720	>720
Time to < .05 mm (hr)	0	0	>720	0	0	1.0	>720	-	140	0	>720	>720	0	>720	>720	>720
Initial Slick Thickness	0.015	0.24	20	0.014	0.014	0.213	0.184	20	20	0.027	0.77	20	0.006	0.33	20	20
Thickness at 6 Hours	0.012	0.21	10.5	0.012	0	0.189	0.147	10.2	4.1	0.0222	0.71	8.9	0	0.26	6.4	2.8
Thickness at 12 Hours	0.012	0.21	9.6	0.011	0	0.185	.0142	9.3	3.6	0.0219	0.70	8.1	0	0.24	5.7	2.5
Thickness at 48 Hours	0.011	0.2	7.6	0.011	0	0.179	0.134	7.6	2.3	0.0206	0.67	6.6	0	0.23	4.6	2.1
Thickness when viscosity at 5000 cP	0.015	-	12.3	0.014	-	-	0.156	17.6	4.3	0.027	-	16.7	-	0.27	2.9	
Thickness when viscosity at 20000 cP	0.014	0.24	11.4	0.014	-	-	0.151	13.1	3.1	0.020	-	11.9	-	0.25	5.7	2.6
Initial slick width	527	28	150	504	504	28.5	30.0	71	71	1357	40	54	1682	22	145	36
Width at 6 Hours	527	28	200	504	0	28.5	30.0	97	143	1357	40	79	1682	23	245	91
Width at 12 Hours	527	28	207	504	0	28.5	30.0	100	149	1357	40	81	1682	24	256	95
Width at 48 Hours	527	28	226	504	0	28.5	30.0	107	164	1357	40	86	1682	25	274	98
Width at Loss of Slick or 720 hrs	527	28	259	504	0	28.5	30.0	107	171	1357	40	86	1682	25	279	98
Naturally Dispersed Oil (top 10 meters)																
Time when < 5ppm (hr)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Time when < 1 ppm (hr)	-	-	-	-	0.16	-	-	-	-	-	-	-	-	-	-	-
Time when < 0.1 ppm (hr)	-	-	-	-	12	-	-	-	12	-	-	-	24	-	-	-
Peak Concentration (ppm)	.0008	0.001	0.032	0.001	1.05	0.0009	0.009	0.003	0.3	0.0008	0.0007	0.003	0.56	0.006	0.07	0.04
Time Peak Reached (hr)	0.8	0.4	1.82	0.8	0.16	0.24	3.5	1.0	1.0	0.06	1.0	1.0	0.0	2.7	1.0	1.0

Table 6b. Spill Scenario Modeling Result Summary: Spills from Vessels

	Spill Scenario Identifier (refer to Table 4-2 for full description of scenario)							
	13a	13b	14a	14b	14c	15a	15b	15c
Spill Info								
Emulsification Tendency	Av	Hi	Av	Hi	No	Av	Hi	No
Volume Spilled (bbl)	250 k	250 k	10 k	10 k	10 k	3000	3000	3000
Discharge Rate (BOPD)	batch	batch	batch	batch	Batch	batch	batch	batch
Time to Visc.>5000 cP (hr)	166	22	90	19	-	74	17	208
Time to Visc.>20000 cP (hr)	188	120	112	63	-	91	48	-
Time to Loss of Slick (hr)	>720	>720	665	375	560	535	273	208
Time to < .05 mm (hr)	>720	>720	650	375	255	520	271	204
Initial Thickness	20	20	20	20	20	20	20	20
Thickness at 6 Hours	12.2	13.1	6.0	6.8	4.1	4.2	4.8	2.8
Thickness at 12 Hours	10.3	11.8	4.7	5.9	3.1	3.2	4.1	2.1
Thickness at 48 Hours	6.5	10.0	2.7	4.6	1.7	1.8	3.2	1.2
Thickness when viscosity at 5000 cP	4.1	10.9	2.0	5.4	-	1.53	3.9	0.025
Thickness when viscosity at 20000 cP	4.0	8.6	1.9	4.4	-	1.49	3.2	-
Initial Width	1457	1457	318	318	318	174	174	174
Width at 6 Hours	1716	1663	527	496	646	342	320	421
Width at 12 Hours	1846	1714	590	523	716	385	338	464
Width at 48 Hours	2272	1794	743	561	841	485	362	539
Width at loss of slick or 720 hrs	2769	2079	847	615	927	531	386	582
Time when < 5ppm (hr)	-	-	-	-	-	-	-	-
Time when < 1 ppm (hr)	-	-	-	-	-	-	-	-
Time when < 0.1 ppm (hr)	540	>720	665	48	260	48	17	108
Peak Concentration (ppm)	0.7	0.3	0.35	1.2	0.94	0.27	0.16	0.75
Time Peak Reached (hr)	24	12	12	6	12	6	6	6

5. Logistics and Feasibility of Operations

Detailed analyses of dispersant logistics were conducted for the above scenarios. The objective was to assess the current response capacity of California spill response resources as tested against the selected spill scenarios. The two factors that are most critical in this analysis are: a) the availability of dispersant resources; and b) the capability of various platforms for delivering and applying the dispersant.

5.1 Inventory of Dispersant Product and Spraying Platforms.

The amount of dispersant available in California will vary from time to time, but at present approximately 41,560 gallons (=989 barrels)is available in stockpiles. Based on the 1:20 rule of thumb, this quantity would be sufficient to fully treat a 20,000-barrel spill. A quantity of 273,615 gallons (=6514 barrels) is held in North American stockpiles outside California, for a total amount of 315,175 gallons (=7504 barrels) of dispersant. At least a portion of the 6514 barrels could be made available for use on a spill in California. Using the 1:20 rule, the total North American stockpile of dispersant is sufficient to fully treat a spill of approximately 150,000 barrels.

Only a limited amount of dispersant response equipment is in place in California at present. In Southern California there two ship-based systems, and two Simplex helicopter bucket systems, all located in Carpinteria. There are no dispersant delivery systems in place in the San Francisco area, although Clean Bay Cooperative is in the process of acquiring a ship-based system. There is a considerable quantity of high capacity response equipment located throughout North America that can be cascaded to California in the event of a large spill. Realistically, however, these outside resources would be available for a California spill only on the second day of response or later. Some features of key spraying platform types are as follows.

- The C-130 equipped with the ADDS Pack (Airborne Dispersant Delivery System) has the greatest overall dispersant delivery capacity of any existing platform. In theory a single C-130/ADDS Pack system might be capable of fully treating all of the oil spilled in the above blowout spills and in the 10,000 bbl batch spills. Its main drawback in California is that at present the nearest ADDS Pack units are outside the state, so start-up times may be lengthy and spraying may not begin until the second day of the spill.
- The DC-4 platform (modeled after the dedicated dispersant spraying aircraft owned by Airborne Support Incorporated of Houma, LA) has a delivery capacity approximately one-half that of the C-130 ADDS Pack. As with the ADDS Pack, the earliest this aircraft can begin spraying dispersant in California is probably the morning of the second day.
- The Cessna AT-802 (Air Tractor) is a single engine aircraft that is purpose-built for aerial spraying. They are capable of having a fairly short start-up time, but have a smaller payload than the larger, multi-engine aircraft and have a limited range. In the U.S., a group of operators offer a dispersant spraying service using this aircraft. One advantage of this platform is that a number of them are available for use in a large spill.
- Spray-bucket-equipped helicopters are available in southern California. Their small payload and short range limits their usefulness. However, their availability, maneuverability and ability to be re-supplied near the spill site make them ideal for responses to production spills or small spills of any kind.

- Ship-based systems vary widely in their operational capabilities (e.g., payloads, pump rates and swath widths). In general, the relatively small payloads and slow transit speeds of most vessels severely limit their capabilities. However, recently developed larger, high-speed crew-cargo vessels, equipped with portable dispersant spray systems may greatly improve the overall performance of this group. There are only two ship-based systems currently available in California and at least one more system is planned. Due to the slow transit speed of this type of platform, it is unlikely that systems from outside California would be available to respond to a spill, except in the event of a prolonged continuous spill.

5.2 Analysis of Logistics

Tanker spills may occur at any point in California's offshore waters and these may be of any size and have short, medium or long TW. The present analysis suggested that ship- and helicopter-based dispersant systems may be adequate to deal with small and mid-sized tanker spills provided that they occur close to their bases of re-supply and the TW is long enough. However, these platforms are limited in their capability to respond to spills at a distance from their base of operations either because of slow transit speed and limited operating range. These limitations can be overcome in some circumstances by re-supplying the platforms at or near the spill site.

The small- to mid-sized spills that occur at considerable distance from the response centers appear to be well suited to the small, fixed wing aircraft, provided the TW is long enough to accommodate their slower startup time. Very large spills appear to require the delivery capacities of the large, fixed-wing platforms, such as the C-130/ADDS Pack system. However, at present, this system is useful only for spills with longer (several days) TW, given that the startup time for these systems is at least 24-hours. Spills of Hi-E oils, of the kind analyzed here (TW<24 hours), are amenable only to locally based resources that can respond within hours. For these spills, the startup times of resources based outside California may be too long to be useful. The present analysis suggested that when spills involve Hi-E oils, even the smaller spill scenarios described in the ACPs require multiple platforms in order to deliver dispersant within the TW.

Production-related spills in California appear to pose difficult challenges for dispersant planners. Many of the spills analyzed here, including all spills of Hi-E oils and subsea blowouts appeared to be poor candidates for chemical dispersion, because of very rapid emulsification (short TW) in certain cases and rapid natural dissipation in others. The above sea blowouts of Av-E oils appear to be good candidates for treatment using ship-based or helicopter-based systems because these systems can remain on-scene and deliver dispersants constantly, as needed. Happily, discharge rates of worst-case blowouts described in contingency plans for California fields are low enough to be within the capacities of vessel- and helicopter-based systems.

It is important to reiterate that the performance of the ship-based system is limited by both their slow transit speed and small payload. In this analysis we have used the characteristics of systems that are currently available in California (payload =1000 gallons, transit speed 7 knots). Larger and faster vessels are currently in use elsewhere and could be developed in California.

6. Net Environmental Benefit of Dispersant Use

A detailed analysis of selected scenarios was conducted to assess the net environmental benefit (NEB) of using dispersants to treat spills in Southern California. The work focused on the area in Southern California where the MMS-regulated oil production facilities are located and addressed both batch and blowout spills. A wide range of possible launch points and spill conditions were considered for analysis and three scenarios were selected, all located in the Santa Barbara Channel area (See table below and Figure 1). The three scenarios were based on spill situations already analyzed by local organizations (e.g., ACPs), so that the results could be related directly to on-going planning problems.

Scenarios Included in Net Environmental Benefit Analysis

Name	Scenario No.[1]	Spill Source	Spill Condition	Location	Season
San Miguel Island (SMI-BS)	14a[2]	Tanker	Batch spill, 10,000 barrels on ANS[3]	N. end of San Miguel Island	Winter
Santa Barbara Channel (SBC-BS)	14a[4]	Tanker	Batch spills, 10,000 barrels of ANS	Middle of Santa Barbara Channel	Winter
Platform Gail Blowout (PG-BO)	11[5]	Platform Gail	Above sea blowout, 883 BOPD x 30days 26460 barrels of Sockeye	34.125N, 119.400W	Autumn

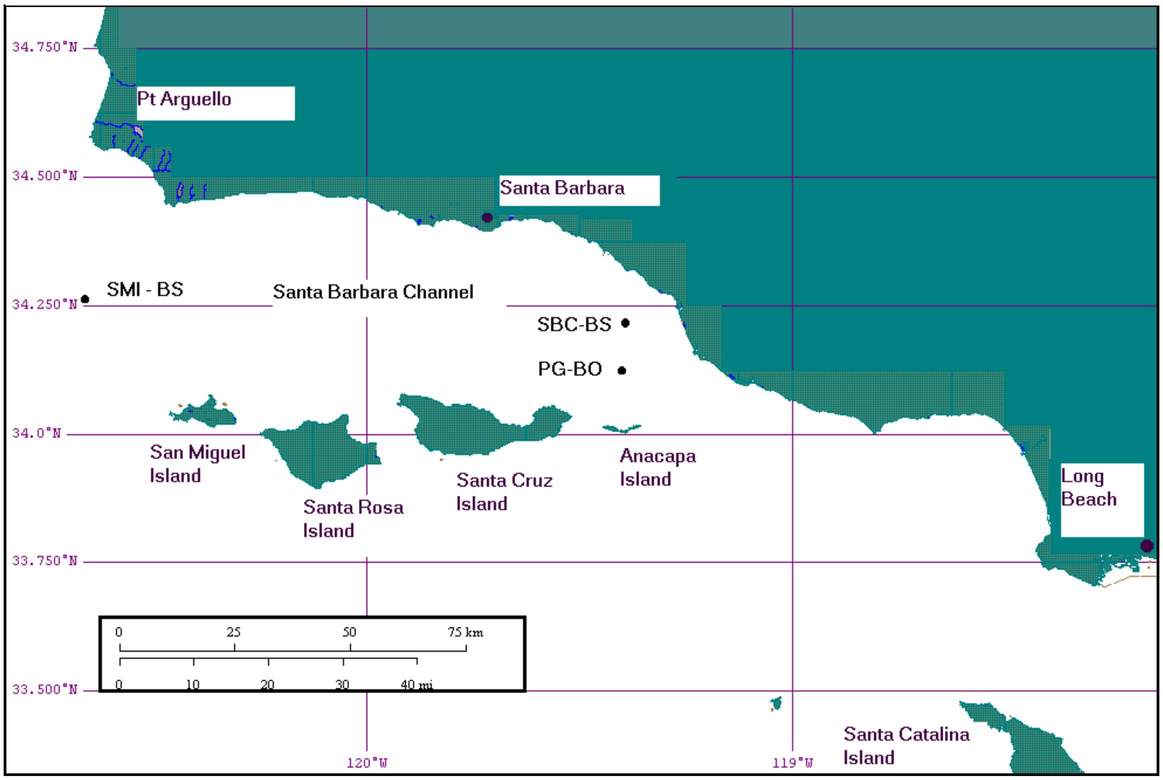
1. See Table 5 and 6 above
2. USCG 2000 Area Contingency Plan: Los Angeles/Long Beach - Northern Sector/Max. Most Probable Discharge, p 4700-9
3. ANS = Alaska North Slope Crude Oil
4. USCG 2000 Area Contingency Plan: Los Angeles/Long Beach - Northern Sector/Worst-Case Discharge, p 4700-1
5. Venoco Inc. 2001. Platforms Grace and Gail; Oil Spill Response Plan – Worst Case Discharge Scenario

Environmental impacts and net environmental benefits were assessed as in an earlier MMS dispersant technology study(S.L. Ross 2001, Trudel et al 2001). In each scenario, the impacts of chemically dispersed and untreated cases were estimated using an oil spill impact assessment model. The impact assessment procedure identifies all resources at risk from the spill and estimates the quantitative impact on each, integrating information concerning: a) the fate, behaviour and movements of oil; b) sensitivity (toxicity) of resources to oil; and c) vulnerability and recovery potential of the target populations. Spill trajectories for batch spills were based on published in contingency plans. The trajectory for the single blowout spill was based on MMS-supported Oil Spill Risk Analysis work (Johnson et al. 2000). The definitions and spatial distributions of target stocks were based on the NOAA ESI database for California (NOAA 1999a,b), supplemented with the MMS marine wildlife database (MMS 2001). Impact was described using the categories, criteria and naming conventions of Pond et al. (2000), because local workers were already familiar with these terms. Net environmental benefits of dispersants were assessed for each scenario by comparing the impacts of the untreated and chemically dispersed cases. Methods are fully described in S.L. Ross (2002).

6.1 Summary of Results

Dispersants offered a net environmental benefit in all three scenarios analyzed. The reason for this is that the launch sites for all spills were somewhat offshore where chemical dispersion pose limited risk. If spills were left untreated, slicks would move onshore where they would pose significant environmental threats to a numerous valued resources. As a consequence, impacts of the untreated spills would always be greater than those of dispersed spills.

Figure 1 Locations of Spill Sites



The spill scenario off San Miguel Island (Figure 1, SMI-BS) was the simplest of the three considered here and was typical of spills occurring outside the Santa Barbara Channel that threaten the Islands. The net environmental benefit of dispersants was clear in this case because the untreated spill threatened very significant damage to important wildlife in the coastal waters of San Miguel Island. On the other hand, chemical dispersion posed few, if any environmental risks for two reasons: a) chemical dispersion could be completed well offshore away from sensitive coastal zone resources; and b) surface currents kept the dispersed oil offshore and carried it away from sensitive nearshore targets, such as the giant kelp forests.

The Santa Barbara Channel batch spill scenario (Figure 1, SBC-BS) off Port Hueneme was somewhat more complex than the SMI-BS in that it took place close enough to shore that some dispersed oil was carried into shallow nearshore waters. The net environmental benefit in this case still favored dispersants because the untreated oil posed important risks to wildlife and human use resources, while the dispersed oil posed few environmental risks. The reasons for the low risk from the dispersed oil are as follows: a) the number of in-water resources threatened by the chemically dispersed oil was small compared to the untreated spill (as per the ESI maps); b) hydrocarbon exposure concentrations for in-water resources were relatively low and therefore the risk of toxicity was limited; and c) the species at risk from dispersed oil were widely distributed throughout Southern California, so only a small proportion of the total Southern California stocks of each species were at risk.

The blowout scenario involving Platform Gail (Figure 1, PG-BO) addressed two complicating factors: a) the complexity arising from a blowout spill that lasts many days (as opposed to a batch spill in which the discharge takes place all at once); and b) the problem of a dispersant operation that is less than 100% efficient. Blowout spills pose different environmental threats from batch spills of similar size because of dissimilarities in the fates, movements and patterns of environmental contamination of each. These differences can in turn influence the NEB of dispersant use. Dispersed and untreated blowouts may cause larger or smaller impacts than batch spills of similar size depending on the spill location and the nature of the receiving environment. In the present scenario, the impact of the untreated blowout is smaller than its corresponding batch spill, for a number of reasons discussed in SL Ross (2002). However, the impact of the dispersed spill is negligible, so dispersants still offer a NEB. This result is consistent with studies of similar offshore blowouts in other areas, such as the Gulf of Mexico (S.L. Ross 2001).

In the Platform Gail scenario, dispersants were less than 100% efficient in dispersing the spill, due to operational limitations and this also may have influenced the NEB issue. If dispersant operations had been 100% effective, the net environmental benefit of dispersion would have been very clear in that dispersants would have eliminated the considerable risks posed by the untreated spill, while not increasing the risk to in-water resources appreciably. However, the dispersant operation was only 75% efficient in dispersing the oil. In this case, however, a 75% reduction in the quantity of oil leaving the spill site was sufficient to almost eliminate shoreline oiling and to greatly reduce or eliminate risks to living habitats, wildlife and invertebrates. So, in short, chemical dispersion, even though it was only 75% efficient, did dramatically reduce the risks from the untreated spill, while not measurably increasing the risks to in-water resources.

In short, despite the additional complications of a blowout scenario and incomplete dispersion, in the Platform Gail blowout scenario dispersants offer a clear NEB. It must be borne in mind that this may not be true in all scenarios.

Overall, based on this study, it is reasonable to conclude that for most marine spills of this size in this area, effective chemical dispersion of spills would generally offer a net environmental benefit. This is certainly true for offshore spills and appears to be true for spills in shallower, nearshore waters, as well, with some possible exceptions.

7. Conclusions and Recommendations

While many of the oils produced in the POCSR appear to be poor candidates for dispersants, there appear to be some for which the outlook is positive. In all cases, however, the TWs appear to be relatively short, so it will be necessary respond quickly if chemical dispersion is to be effective. This will involve using response strategies suited to rapid response (i.e., locally based vessel- and helicopter-spray systems), but it may also be useful shorten the travel time for spray platforms by having dispersants and spray gear stored on vessels that service the platforms in question. Fortuitously, the same spraying systems that are well suited to providing quick response are also well suited to dealing with continuous discharges of oil encountered in blowout spills. Moreover, because the oil from production spills may become undispersible quickly, it will also be important to have effectiveness monitoring in place quickly as well.

It is clear from this analysis that the potential for using dispersants to treat tanker spills in California is promising because a sizable proportion of imported oil is dispersible when fresh. Although the vast majority of spills involve small volumes of oil, when tankships are involved, there is always the chance of a large spill. The modeling conducted here suggests that the TW of some imported oils may adequate for dispersant response, but TW are not infinite. In order respond to larger spills in a timely fashion, arrangements should be put in place to use high-capacity spraying systems (e.g., fixed-wing aircraft, high capacity, high speed dispersant spraying vessels). These arrangements must enable responders to begin spraying dispersant within 24 hours of the spill.

An important conclusion is that in the all three spill scenarios examined here, chemical dispersion appears to offer clear net environmental benefits. This conclusion will probably be true for other spills in the Santa Barbara Channel area and it is probably true for spills in nearby offshore areas and shallow, nearshore waters alike. Therefore, for reasons of environmental protection, dispersants should be considered for cleaning up dispersible spills in the coastal zone in this area. One reservation might be in areas near kelp forests, clearly critical living habitat resources. There appears to be little information concerning the sensitivity of kelp fronds to dispersed oil and it would be important to address this deficiency before using dispersants near this important habitat.

From this work, it was clear that the ESI maps for this area were developed for the purpose of estimating the impact of undispersed oil spills, not chemically dispersed spills. These maps contain extensive information concerning resources that are sensitive to untreated oil, but the information concerning dispersed-oil-sensitive resources appears to have been less complete and less detailed. The same problem was identified in ESI maps for other areas in other studies. Based on experience with NEB analyses conducted in other areas, it is unlikely that better documentation of in-water resources in ESI maps would have changed the overall outcome of this study. However, better documentation of in-water biological and human-use resources may have strengthened the conclusions of this study and might reassure stakeholders that the resources in which they were interested were given full and proper consideration.

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Appendix

The following table contains parameter values used in the SLROSM oil fate model for two typical oils, Alaska North Slope crude oil and automotive diesel fuel.

Table A-1 Example Model Parameters Used in Modeling

Model Parameter	Alaska North Slope Crude Oil	Automotive Diesel Fuel
Initial Density	878.1	863.1
Standard Density Temperature	288	288
Density Constant1	178	54
Density Constant2	0.828	0.703
Viscosity	17.3	3.4
Standard Viscosity Temperature	288	288
Viscosity Constant 1	12.9	1.6
Viscosity Constant 2	9294	2236
Oil Water Interfacial Tension	0.020	0.028
Water Interfacial Tension Constant	0.017	0.110
Oil-Air Interfacial Tension	0.032	0.006
Air Interfacial Tension Constant	0.011	1.193
Initial Pour Point	258	186
Pour Point Constant	0.203	0.197
ASTM Distillation Constant A (slope)	723	139
ASTM Distillation Constant B (intercept)	380	561
Emulsification Delay	300000	9999999.0000
Fv Theta A	9.28	6.30
Fv Theta B	12.44	10.30
Initial Flash Point	270	10.3
Flash Point Constant	0.6	0.8